Studies in Carbon and Meteorological Flux and Air Quality Concentration Measurements in the Baltimore Ecosystem Study

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Abstract: We are using a permanent 40m lookout tower at Cub Hill, Maryland Department of Natural Resources, Forest Service, to conduct air quality and meteorological flux research. We will characterize the air quality and meteorological fluxes that come from the urban and suburban residential forested areas. Urban conditions may represent future scenarios of elevated carbon dioxide, ozone, nitrogen deposition and elevated heat island effects.

Carbon exchange between the atmosphere, vegetation and soils will be monitored using atmospheric methods. A CO_2 and H_2O profile system has been installed and is now running continuously. The diurnal CO_2 cycle shows a pattern associated with daytime energy use and rush hour traffic. Highest concentrations measured at the top of the profile exceeded 425 ppm in the late evening, approximately 65 ppm (15%) above ambient. The CO_2 cycle for the weekends in the winter appears to have lower overall CO_2 emissions than that of the weekdays. This poses an interesting contrast between flux obtained during the growing season at possibly higher CO_2 and pollution levels during the weekday versus flux under lower CO_2 concentrations during the weekend and holidays.

An open path CO_2 flux system has been installed and tested for compatibility with existing radio equipment at the tower. The flux, meteorological, and air quality measurements include CO_2, H_2O, input and partitioning of radiation (net, solar, PAR, IR, UV), sonic anemometer for 3-D wind speed and direction, precipitation, relative humidity and air temperature. Nitrogen deposition and ozone concentrations will be measured with active and passive analyzers.

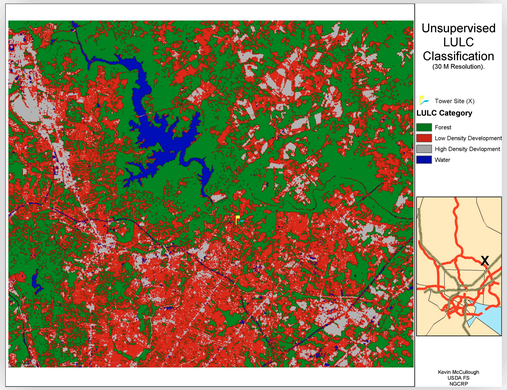

Fig. 1. Unsupervised LULC Classification

Purpose & Objectives: The primary purpose of this research is to measure the net carbon uptake of non-forest lands in forested and developed regions of Baltimore. Land use is the most significant factor affecting forests. It is estimated that 80% of the U.S. population will live in urban areas by the year 2025, up from 74% in 1986. With an average tree cover of 33.4%, metropolitan areas (urban counties) support 25% of the Nation's total tree canopy cover. However, estimates of suburban forest area and the amount of carbon stored in this land use classification are not as well known, as they fall between the inventories of rural and urban forests. The estimates of carbon stocks and flux for these non-forest/suburban areas are the greatest source of uncertainty in the US Forest carbon budget.

We are using a permanent 40m lookout tower at Cub Hill to collect continuous measurements of meteorological and air quality variables. This will be the first permanent tower to measure carbon flux in an urban/suburban environment. This would be valuable tool to improve and add to our stocks inventory information for areas traditionally called non-forest lands. Non-forest lands are defined as less than acre in size, less than 120' wide, less than 10% stocked (canopy cover), and has other land use or disturbance.
By using wind direction and different land use "footprints" around the tower, it may be possible to characterize the air quality and meteorological fluxes that come from suburban residential and more forested regions.

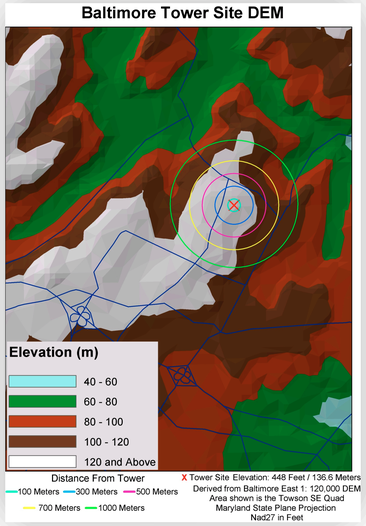

Fig. 2. Baltimore Tower DEM

Fig. 3. Aerial Photo of Region

Site Description and Methods: The tower site is located on a Maryland DNR Forest Service site at Cub Hill, approximately 30 km NE from the center of Baltimore and 3 km from a major highway. (Fig.1, 4). The tower is on a broad knoll (Fig. 2, 3), with a yellow poplar-oak-hickory forest at the base and a canopy height of 20-25 m. Immediately south is a residential area with large areas of forest and vegetated open space to the north and west.

We will use eddy-covariance methods to estimate carbon flux and carbon sequestration in urban/suburban forest ecosystems (Fig. 5). This will involve developing methods to study carbon flux in non-uniform urban/suburban environments and complex terrain (Fig. 2).
The flux system uses a Licor 7500 open path CO_2/H_20 analyzer with a RM Young 81000 sonic anemometer (Fig. 6). A Kipp & Zonen net radiometer (Fig. 7, 8) and two Campbell data loggers at the top and bottom of the tower monitor sensible heat flux, latent heat flux, CO_2 flux, net radiation and soil heat flux. A Licor 6262 closed path CO_2/H_20 analyzer and a Scanivalve 12 port solenoid are used for the profile system (Fig. 8). Two IBM PCs control the flux and profile systems.

The study would complement AmeriFlux and Fluxnet programs to measure CO_2 exchange from major terrestrial ecosystems, natural and managed, to determine the factors that control the rate of net carbon storage. This network provides long-term monitoring of inter-annual measurements of CO_2, water and energy exchange for intact forest and vegetated areas as well as non-forested areas.

The flux tower will improve our ability to verify carbon storage on an annual basis in these non-traditional forest areas and improve and add to our stocks inventory information used in our national carbon budget. The Forest Inventory and Analysis (FIA) is conducting a pilot study and collecting forest inventory information on plots traditionally called "non-forest" in Baltimore which will provide some of the monitoring of these "non-forest" plots Fig. 13). In the State of Maryland, 44% of the non-forest plots contain some tree cover.

Fig. 4. Cub Hill Tower

Fig. 5. Residential Area around Tower

Fig. 6. CO_2 and H_2O Flux Instrumentation

Science questions and goals: The tower site will play a major role in the air quality and meteorological flux research for the Baltimore Ecosystem Study (BES). The urban/suburban flux site will provide new scientific research opportunities and will address these science questions:

- Characterize the elevated levels of CO_2, temperature, and nitrogen deposition in urban/suburban sites.
- How does temporal cycles affect the atmospheric composition of ozone, N deposition, and CO_2 concentration i.e. diurnal traffic/rush hour, workweek vs. weekends?
- How much carbon does the suburban ecosystem sequester, and how does it compare with rural forested systems?
- Can we distinguish the effects of atmospheric fertilization (CO_2, N deposition) on carbon uptake storage and net productivity?
- What are the effects of climatic variation, and the urban heat island effect on the annual net uptake of CO_2?
- How does built structure and vegetation affect heat, water and carbon dioxide exchange in an urban-suburban ecosystem?
- What new methodologies are needed for ecosystem carbon flux measurements in an urban-suburban footprint?

Fig. 7. Net Radiometer

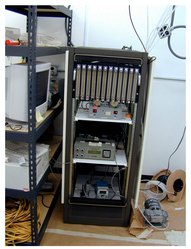

Fig. 8. Co_2 Profile System

Manufacturer	Instrument	Serial No
R.M. Young	Sonic anemometer	00293 (81024 41-99)
Campbell Scientific	23X datalogger	2851
Hoffman enclosure	for 23x	
Campbell Scientific	Multiplexer AM16/32	1217
Hoffman enclosure	for multiplexer	
Campbell Scientific	CR10 datalogger	14392
Licor	Li- 7500 CO2/H20 analyzer	75H-0204
Weathertronics	6011B raingauge	1165
CSI	Soil heat flux plates (2) HFT 1	90151 90182
CSI	Soil temperature sensor TCAV	
CSI	Soil moisture sensor TDR CS-615	8868 LT#436738 8221-07
Kipp & Zonen	CNR1 net radiometer	012093
CSI	237 Leaf wetness sensor (2)	
RM Young	Wind Sentry Anemometer and Vane	IU1
Omega Engineering	Thermocouple: 5SC-TT-T36-36 -0.005 wire: TT-T-24-TWSH-SLE 0.2F dev at 119.4 F	
CSI RM Young T/RH shield	500 Temperature & Relative Humidity sensor	V0620004
Vaisala	PTB101B Pressure Transducer	V3510019
Licor	LI-6262 closed path CO2/H20 Analyzer	
Scanivalve	12 port solenoid	
Remote Systems	ADC-1 data acquisition board	
Data Design Group	Custom 12 port Scanivalve controller and DAC	

Fig. 9. Instrumentation

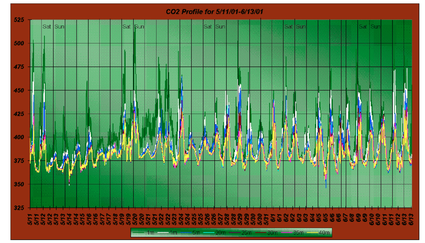

Fig. 10. Co_2 Profiles at Different Levels

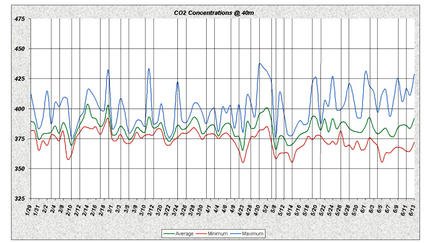

Fig. 11. Co_2 Concentrations at 40m

Results and Accomplishments: The 10 level profile system was initiated in February 2001. The preliminary results of our CO_2 profile system during the showed a diurnal cycle associated with energy use, rush hour traffic and lack of vegetation response from the dormant tree cover during the winter. Highest concentrations measured at the top of the profile exceeded 425 ppm in the late evening, approximately 65 ppm (15%) above ambient. The weekly CO_2 cycle shows possibly lower overall CO_2 emissions for the weekend than that of the weekdays during the winter, however this was less obvious in the spring and summer (Fig. 10,11). The CO_2/H_20 flux system was operational in May 2001. Preliminary data for daily CO_2 flux, latent heat flux, sensible heat flux, net radiation and soil heat flux is presented for July 3, 2001 (Fig. 12). We have also initiated:

- ·Cooperative agreement with Dr. Sue Grimmond, Indiana University for urban flux comparison with towers in Poland and France with Baltimore.
- ·Cooperative agreement with Dr. David Nowak, Urban Forestry Research Work Unit, for urban forest plots for vegetation and carbon sampling around tower site.
- ·Initiated site comparison with rural (cleaner, less polluted) tower site with Dr. Jess Parker, Smithsonian Environmental Research Center (SERC) tower site.
- Initiated installation of dry nitrogen deposition profiles and plans to measure NO_x and O_3 concentration using active and passive analyzers
- Linked to ongoing research at the BES LTER, FIA pilot study on monitoring "nonforest" plots, the AmeriFlux Network of flux towers, and the US Forest Carbon Budget.

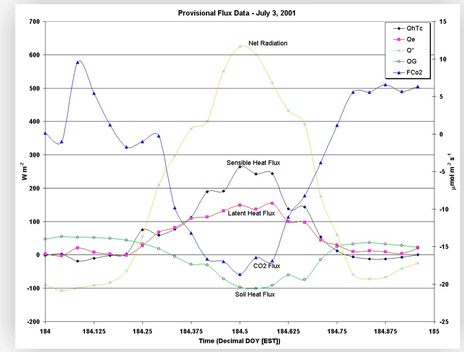

Fig. 12. Co_2, H_2O and Energy Flux

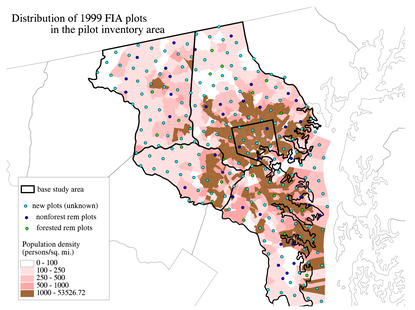

Fig. 13. Distribution of FIA Plots

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